BULLETIN NO. 178 MARCH, 1901

THE NORTH CAROLINA
COLLEGE OF AGRICULTURE AND MECHANIC ARTS
AGRICULTURAL EXPERIMENT STATION DEPARTMENT
GEO. T. WINSTON, LL.D., DIRECTOR

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The Nature of Pentosoids, and Their Determination

G. S. FRAPS

WEST RALEIGH, N. C.
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Publications sent to any address in North Carolina upon application.

THE NORTH CAROLINA COLLEGE OF AGRICULTURE AND MECHANIC ARTS

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LETTER OF TRANSMITTAL.

THE NORTH CAROLINA
COLLEGE OF AGRICULTURE AND MECHANIC ARTS.
AGRICULTURAL EXPERIMENT STATION DEP'T,
DIVISION OF CHEMISTRY.

WEST RALEIGH, N. C., March 20, 1901.

SIR:—In Bulletin number 172 of this Station, the Chemical Division called attention to the fact that there was a wide variation in the digestibility of the non-nitrogenous constituents of feeding stuffs which make up the nitrogen-free extract and crude fiber, and with these facts as a basis urged that, in digestion experiments, there be made determinations of the amounts of sugar, starch and pentosans. The accompanying Bulletin, by Dr. G. S. Fraps, Assistant Chemist, is a continuation of work along this line, containing a summary of the existing knowledge of the pentosoids and, in addition, a contribution to the knowledge of their properties, relating more especially to their estimation.

A feeder of very limited experience does not need to be told that certain classes of feeding stuffs are better for beef cattle and others for milch cows. It does not require very much additional experience to enable one to calculate a ration based upon the well-known feeding standards and the chemical composition of the usual feeding stuffs. But, in connection with the subject of animal nutrition, metabolism, etc., we are confronted with problems which puzzle the biologist as well as the chemist. The purpose of the work embodied in this Bulletin was to seek for information in regard to these intricate problems. The result of this and similar work may not be of benefit immediately to the stockman, but when the chemist, after patient investigation, has greatly increased the store of knowledge as to the changes which take place in the animal body, the results will then be of the greatest benefit to him.

Very respectfully,

W. A. WITHERS,
Chemist Agricultural Experiment Station.

To Dr. GEO. T. WINSTON,
Director.

The Nature of Pentosoids, and Their Determination.

G. S. FRAPS, PH.D., ASSISTANT CHEMIST.

The term "pentosan" is applied to those substances, occurring in plants, which are converted into furfural when distilled with hydrochloric acid. The name implies that these substances are derivatives of pentose sugars, just as cellulose and starch $(C_6H_{10}O_5)_n$ are derivatives of hexose sugars, and that by hydrolysis they should be converted into hexoses. The formula of the pentosans would be $(C_5H_8O_4)_n$, and their hydrolysis could be represented thus:

$(C_5H_8O_4)_n + {}_nH_2O = {}_nC_5H_{10}O_5$:

Inasmuch as it is not certain that all the so-called pentosans are hydrolized to pentoses, a better term to designate them would be, pentosoid, *i. e.*, pentose-like, in that they yield furfural.

The pentosoids are widely distributed in nature. They are found in the wood of trees, in hays, fodders, the stems of plants, especially in those rich in crude fiber, and in seeds, more especially in their outer envelopes.

CLASSES AND NATURE OF PENTOSOIDS.

It is possible to divide the pentosoids into several classes, which, while not sharply defined, are sufficiently so to show the diverse nature of the substances the group contains.

(1) *Water-soluble pentosans.* No pentosans $(C_5H_8O_4)_n$ are known which are solubie in water; it is possible that these water-soluble pentosans are pentose sugars. Stoklosa [Central-Blatt f Agr. Chem.: *29*, 104 (1900)] found 62.4 per cent of the furfural-yielding substances of sugar beet seed to be soluble in water; 64.5 per cent in the five-day old sprouts; in the leaves of 10-day plants, 66.9 per cent, in the roots, 19.6 per cent; in the leaves of the 120-day old plant, 39.8 per cent, in the roots 14.1 per cent water-soluble. De Chalmot [Am. Chem. J.: *15*, 21 (1893)] found very small quantities of water-soluble pentosans in the leaves and bark from a number of plants.

(2) *Pentosans soluble in hot dilute acids.* E. Schulze [Ber. d. Chem. Ges.: *24*, 2277 (1891)] proposed the term hemicellulose

for constituents of the cell walls of plants (hexosans or pentosans) which are easily hydrolized by dilute mineral acids. They appear to be soluble in hot dilute alkalies, and very slowly in 5 per cent sodium hydroxid. Pentoses as well as hexoses are found among the products of the hydrolysis of hemicelluloses, examples being wheat bran, rye bran [Ber. d. Chem. Ges.; *23*, 3110 (1890)], and the seeds of the Leguminosae, as lupine, soja bean, [Ibid: *24*, 2777 (1891)], so that we have reasons for calling them pentosans.

(3) *Alkali-soluble pentosans.* By extraction of woods and other plant substances with 5 per cent caustic soda solution (cold), or lime-water, and subsequent precipitation with alcohol, (with or without neutralization), gum-like substances are obtained, many of which have been hydrolized to pentose sugars, and so can be considered as containing pentosans. The gums from the following materials have been hydrolized to xylose: from beech wood (gum was 4 per cent of the wood), fir wood (0.4 per cent), jute (1.73 per cent) [Ann. Chem. (Liebig): *254*, 307 (1889)]; from wheat straw (16.2 per cent), cherry wood (12.4 per cent) [Ibid: *260*, 289 (1890)]; from laurel wood [Landw. Vers. Stat.: *39*, 461 (1891)] and from corn cobs (8 per cent) [Am. Chem. J.: *13*, 348 (1891)].

The gums obtained from wheat bran, rye bran [Ber. d. Chem. Ges.: *23*, 3111 (1890)] and lupines [Ibid: *24*, 2285 (1891)] have been hydrolized to arabinose. The gum from vegetable ivory has been hydrolized to mannose, a hexose sugar [J. Am. Chem. Soc.: *18*, 214 (1896)]. Natural gums appear to contain pentosans; cherry gum, gum arabic, gum myrrh, gum tragacanth, sugar beet gum (rare), and others, have been hydrolized to pentose sugars.

It is not certain whether wood gum exists in the plant substance as such, or is formed by the action of the caustic soda upon some other material. Tollens and Schulze [Landw. Vers. Stat.: *40*, 367 (1892)] suggest that cellulose and wood gum are not a simple mixture, but are intimately combined, perhaps as a chemical compound in the lignified cell, and that lignin is present as a third group, or it may be that cellulose itself contains pentose groups, being made up of a number of groups $C_5H_8O_4$ and $C_6H_{10}O_5$ chemically united.

Some wood gums, as they exist in the plant, are easily brought into solution by hot dilute mineral acids, and would fall into the preceding class, but others are very resistant towards acids and not until dissolved in caustic soda do they become so modified as to be easily hydrolized by acids.

Hoffmeister [Landw. Vers. Stat.: *48*, 401 (1896)] uses the term hemicellulose to designate the non-nitrogenous portions

of the plant cells soluble in 5 per cent caustic soda (wood gum). Wheat bran contains 16.8 per cent, rye bran 16.8 per cent, linseed cake 2.5 per cent. Hoffmeister uses the term in a meaning different from that given it by Schulze.

It requires repeated extraction with caustic soda solution to remove the wood gum. Cellulose prepared by different methods usually contains a small quantity of wood gum, either the original "gum" of the plant, or gum formed by the action of the reagents used for separating the cellulose. Cellulose may be changed to modifications soluble in caustic soda by dissolving in ammoniacal copper oxide, and precipitating. [Landw. Vers. Stat.: *39*, 461 (1891)].

The term pentosan can be applied to the furfural-yielding constituents of the wood gums, since many of them have been hydrolized to pentose sugars, although at times the yield has been far from satisfactory.

(4) *Furfuroids.* Plant substances containing pentosoids which have been subjected to the hydrolytic action of dilute mineral acids, and the solvent action of 5 per cent cold caustic soda solution, still contain, as a rule, considerable quantities of furfural-yielding constituents, and it is doubtful if the name pentosan can be applied to these. The portions of a plant cell, not cellulose, which are very resistant to hydrolysis, are often called "encrusting matters," or "lignin," and contain furfural-yielding groups. According to Cross and Bevan (Cellulose, p. 93), they should be called lignocelluloses, since it appears probable that the lignin and cellulose are in chemical combination. It has not been proved that the furfural-yielding group of lignin can be hydrolized to pentose sugars; on the contrary, certain reactions seem to show that lignin and other furfural-yielding constituents are not derivatives of the pentose sugars. By treating jute (a lignocellulose) with carbon bisulphide and caustic soda, and separating the insoluble and water soluble portions, a reduction of the furfural-yielding group 50 per cent was effected. (Cross and Bevan "Cellulose," p. 122). Esparto cellulose (an oxycellulose) yields 12 per cent of furfural; by reduction with solutions of zinc-sodium hyposulphite, the yield of furfural was reduced to 8–9 per cent. Esparto cellulose was also reduced by carbon bisulphide and caustic soda, the furfural from the soluble and insoluble portions being 6 per cent, or one-half of the original. (Cellulose, p. 85). These experiments seem to show that a portion, at least, of the furfural-yielding constituents of plant tissue does not consist of pentosans $(C_5H_8O_4)_n$, but of bodies which can be reduced, possibly oxyhexoses. Inasmuch as this body is reduced by caustic soda and carbon bisulphide to half its former power to yield furfural, a

possible theory is, that they are hexoses in which one of the alcoholic groups CH_2OH has been oxidized to an aldehyde group CHO, which, like many other aldehydes, (furfural for instance) is oxidized and reduced at the same time by caustic soda solution, to COOH, and CH_2OH groups. It is well known that other bodies than the pentose sugars, and pentosans yield furfural by distillation with hydrochloric acid.

Glycuronic acid, the oxycelluloses made by oxidizing cellulose with different reagents, the osones, which can be formed by oxidizing sugar with hydrogen peroxide [J. Chem. Soc.: *73*, 467 (1898); *75*, 787 (1899)] all yield furfural when distilled with hydrochloric acid.

According to de Chalmot, pentosans are formed in the plant by the oxidation of hexoses, and he offers the following hypothesis [Am. Chem. J.: *16*, 610 (1894)]: "Pentose molecules are formed in complex molecules of hexosans (celluloses and hemicelluloses) in which a part or all of the aldehyde groups are bound by condensation and are thereby preserved from further oxidation. Pentose molecules are formed from hexoses by the alcohol group at the end of the hexose molecule being oxidized to carboxyl, and carbonic acid being split off. I wish to leave it undecided whether there are some pentosan molecules in which the aldehyde or carboxyl groups still adhere. This is, however, not impossible."

This hypothesis would explain, in a satisfactory manner, what has been noted above. The molecules in which the aldehyde or carboxyl groups still adhere, could hardly be called pentosans, however, meaning by pentosans, derivatives of the pentose sugars. Pentosoids would be a more suitable term.

According to Cross and Bevan [J. Am. Chem. Soc.: *18*, 8 (1896)] straw cellulose consists of

	Per Cent.	Yielding Furfural, Per Cent.
Lignocellulose	33.0	2.6
Resistant cellulose	25.0	2.6
Hemicellulose	21.0	....
Pentosans	21.0	9.0

Methyl pentosoids. These occur in a number of plants, as it has been shown by B. Tollens [Ber. d. Chem. Ges.: *33*, 143 (1900)] that methyl furfural is formed when they are distilled with hydrochloric acid.

Pentosoids in crude fibre. As has been pointed out by Konig [Landw. Vers. Stat.: *48*, 81 (1897)], and others, crude fiber prepared in the ordinary way may contain a considerable percent-

age of furfural-yielding substances. If pentosoids are to be determined in the course of regular feeding-stuff analysis, if one does not desire to consider them entirely separate from the other work, it would be necessary either to make two determinations of pentosans (one of total, and one in the crude fiber), or else to adopt a method for determining crude fiber in which all the pentosans are dissolved. A method of this kind has been devised by J. Konig [Analyst *23*, 47 (1898)].

The pentosoids in the crude fiber have a lower digestibility than the pentosoids in the nitrogen free-extract (Bull. 172 this Station).

DIGESTIBILITY OF PENTOSOIDS.

	In N-Free Extract, Per Cent.	In Crude Fiber, Per Cent.
Timothy hay I	58.1	46.9
Timothy hay II	57.0	52.0
Green rape I	95.7	84.6
Green rape II	93.2	75.9

ASSIMILATION OF PENTOSOIDS.

The digestibility of the pentosoids has been discussed to a certain extent in a previous publication of this Station (Bulletin 172): it ranges from 45 to 95 per cent, depending on the feeding-stuff. But the question arises, of what value are the pentosoids to the animal? Are they assimilated, and utilized?

In regard to the products of the hydrolysis of pentosans (pentose sugars) the following is known:

Ebstein found that pentoses are not suitable for the nutrition of men.

Cremer states that it is not proven that the pentoses are not assimilated by rabbits.

Salkowski found that rabbits can utilize arabinose, but about one-fifth of the sugar fed is excreted unchanged from the organism, in the urine. [Jahresber. f. Agr. Chem.: *15*, 372 (1892) abs.]

Frentzel [Ibid.: *17*, 415 (1894)] found no glycogen in rabbits after feeding the glycogen-free animal with xylose. He concludes that xylose can not form glycogen, or influence the formation of glycogen by being oxidized in place of other glycogen-forming substances.

Goetz and Pfeiffer [Landw. Vers. Stat.: *47*, 59 (1896)] fed a sheep on cherry gum (with lucerne hay), and on arabinose, and found no determinable quantity of pentoses or furfural-yielding substances in the urine; the formation of hippuric acid

seems to depend to a certain extent on the pentosans fed, increasing as they increase

The conclusion from these experiments is, that pentoses are of no value to the human organism, but are assimilated, and utilized, more or less completely, by herbivorous animals.

Cross, Bevan, and Remington [J. Am. Chem. Soc.: *22*, 633 (1900)] fed a rabbit on the products of the hydrolysis of brewers' grains with sulphuric acid, the acid-free extract yielding 35.9 per cent furfural on dry matter. The digestibility of the furfural-yielding constituents was from 94.5 to 98.4 per cent.

No pentosans or other furfural-yielding products were present in the urine. In view of the other experiments here cited, their conclusions do not seem to be entirely justified: "It may be concluded from these results that the typical furfuroids of cereal tissues when fully hydrolized are digested and assimilated by the herbivora as completely as starch and the products of its hydrolysis. In this respect they differ from the pentoses and their anhydrides." The last statement is the one which does not seem justified.

That the pentosoids contribute to the formation of fat and flesh is shown by the experiments of Kellner, and Kohler [Landw. Vers. Stat.: *51*, 53 (1900)]. Digestible fiber (containing pentosans) was as valuable as starch.

DETERMINATION OF PENTOSOIDS.

The method of determining pentosoids used in this laboratory is described in full in Bulletin 172.

It consists in distilling the substance with hydrochloric acid of 1.06 sp. gr., and precipitating the furfural in the distillate with phloroglucol. It is usually assumed that the only product in the distillate which is precipitated by phloroglucol is furfural, but this is not the case. As already pointed out by the writer (Bull. *172*), small quantities of insoluble fatty acids pass over into the distillate, which, while not precipitated by furfural, will appear in the distillate unless previously filtered out. Further, if the distillate is allowed to stand ten or more hours, very often an amorphous black precipitate separates, which would also appear in the distillate, either as such or combined with the phloroglucol, since the vessel is always allowed to stand over night after adding the precipitating agent. Finally, the distillate always contains one or more substances which do not appear to be furfural, and which are precipitated by phloroglucol. These substances will be discussed in the following pages.

FURALOID.

While carrying through the determination of pentosans in a number of materials, the possibility that the distillation with hydrochloric acid might destroy some of the furfural occurred to the writer. This possibility seemed stronger when one of the distillates was evaporated and found to leave a brown residue. To test the point further, corn bran was distilled with hydrochloric acid in the usual way for the determination of pentosans, and the distillate divided into two equal portions. One portion was made up to 500 cc with acid, and precipitated with phloroglucol. The second portion (200 cc) was placed in a distilling flask, and 170 cc distilled. The distillate was returned to the flask, distilled to a small volume, 30 cc acid added, distilled, and the addition of acid and distillation repeated once more. The distillate was made up to 500 cc, and the furfural precipitated with phloroglucol. The weights of the precipitates were, from:

Undistilled portion	0.2216 gram.
Distilled portion	0.1715
Loss	0.0501
Loss, per cent	22.5

Other experiments gave the same result, though the loss was not so great, as the second distillation was never carried out twice.

The question arose, is this loss due to oxidation during the second distillation? That it was not is shown by the fact that the loss was as great when the distillation took place in a current of carbon dioxide as in the air. In performing this experiment, the distillate was divided into several portions, and two portions precipitated directly, after dilution to 500 cc with hydrochloric acid of 1.06 sp. gr. The other portions were placed in distilling flasks, and distilled almost completely, then 30 cc of acid was added, and distilled. The addition of acid and distillation was repeated several times, the distillate then made up to 500 cc, and precipitated as before. This is the method used in all subsequent experiments, unless otherwise noted.

Timothy hay was the material used. The weights of the precipitates were, from:

	I	
Undistilled portions	0.2763 gram.	0.2767 gram.
Distilled alone	0.2299	
Loss, per cent	16.8	
Distilled with CO_2	0.2216	0.2236 gram.
Loss, per cent	19.1	19.8

The loss was not caused by oxidation during the second distillation.

Is this loss due to decomposition of furfural? was the next question. To test this point, freshly prepared furfural was dissolved in hydrochloric acid of 1.06 sp. gr., and portions distilled as in the preceding experiment. The precipitates weighed, from:

Undistilled portions.....	0.2815	0.2805 gram.
Distilled portions.....	0.2804	
Loss, per cent.....	none.	

After standing four days, the solution of furfural became brown, probably by oxidation. In this condition, it gave the following results:

Undistilled portions...	0.2880	0.2863	gram.
Distilled portions.....	0.2785	0.2779	0.2762
Mean loss.....			0.0096
Per cent loss.....			3.2

The error of analysis may be 0.0030 on each precipitate, so that the loss is very small.

The possibility still remained, that during the first distillation of the substance with hydrochloric acid, the furfural formed is changed, by oxidation or otherwise, so that it does not pass over during the second distillation. To test this possibility, a solution of furfural was prepared and distilled in the usual way. One portion of the distillate was distilled as before, and a second portion precipitated directly. The results follow:

Distilled once.....	0.4577 gram.
Distilled twice.....	0.4510
Loss.....	0.0067
Loss, per cent.....	1.5

The loss is less than when the furfural solution had stood four days.

These experiments seem to show, that when vegetable materials are distilled with hydrochloric acid, there may be formed, besides furfural, a substance or substances which precipitate phloroglucol, and is destroyed (in part or wholly) by a second distillation. Until more is learned as to the nature of this substance, for convenience's sake, I shall use the term furaloid to designate it.

OCCURRENCE OF FURALOID-YIELDING SUBSTANCES.

The furaloid-yielding substances were determined in the manner already noted, namely, the material was distilled with hydrochloric acid, the distillate divided into two portions, and one portion distilled again. The percentage lost was assumed to represent the percentage of furaloids present in the crude furrural. This method is not supposed to be very accurate, but only to give some idea as to the occurrence of these substances.

The furaloid-yielding substances are widely distributed in nature, as all materials tested contained them. The table shows the percentage obtained by the method just described.

FURALOID IN CRUDE FURFURAL.

	Weight Lost.	Per Cent Lost (Furaloid).
Cotton-seed meal	0 0301 gram.	7.4
Cowpea meal	0.0197	17.9
Crimson clover hay	0.0337	11.7
Irish potato vines	0.0278	10.2
Corn bran	0.0501	22.6
Timothy hay	0.0596	18.1
Pine straw	0.0241	13.2
Gum arabic	0.0338	12.9
Corn cobs	0.0595	10.1
Okra hulls	0.0513	11.5
Oak sawdust	0.0311	6.9
Oxycellulose	0.0148	13.8

None of these losses are small enough to be ascribed entirely to change in furfural. In the table, the distillates from the materials down to pine straw were allowed to stand over night, and filtered before being distilled. The distillates from pine straw and the others were redistilled the same day as prepared. The oxycellulose was prepared by oxidizing filter paper with cromic acid in the presence of sulphuric acid.

In some cases the residue in the flask was evaporated to dryness in a platinum dish, dried, weighed, ignited, and weighed again. The organic matter so determined was, as a rule, about 50 per cent of the loss in weight of the phloroglucid precipitate, but it varied considerably. On account of this variation, and as it is by no means certain that the furaloid was changed to non-volatile substances, little value was attached to these figures, and they are not given.

DISTRIBUTION OF FURALOID-YIELDING SUBSTANCES.

When sustances containing pentosans are boiled with 1¼ per cent sulphuric acid, and then with 1¼ per cent caustic soda, as for the determination of crude fiber, part of the pentosans are dissolved by the acid, part by the alkali, and usually a part remains in the crude fiber.

In order to ascertain to what extent the furaloid-yielding bodies were dissolved by 1¼ per cent sulphuric acid, ten grams of the material were boiled for half an hour with a liter of the acid, filtered and washed. The residue was distilled with hydrochloric acid, and furaloid determined in the distillate. The filtrate was neutralized with barium carbonate, filtered, evaporated to a small volume, and distilled with hydrochloric acid. Furaloid was determined in the distillate. Furfural was given off during the evaporation.

FURALOID IN CRUDE FURFURAL.

	Entire Material, Per Cent.	Dissolved by Acid, Per Cent.	Undissolved, Per Cent.
Corn bran.....	22.6	0	6
Timothy hay.....	18.1	7.3	2
Crimson clover hay....	11.7	7	1

The furaloid-yielding substances were almost completely dissolved by the acid, and at the same time destroyed, entirely, or to a great extent.

About 90 per cent of the pentosans in the corn bran, and 45 per cent of those in the timothy hay, were dissolved by the acid.

DIGESTIBILITY OF THE FURALOID-YIELDING SUBSTANCES.

One experiment was made to see if the furaloid-yielding bodies were more or less digested than the pentosans. The furaloids were determined in the distillate from the excrement from a sheep fed timothy hay, which had been used in digestion experiments.

	Per Cent.
Pentosans digested in hay	55.9
Furaloids in crude furfural from hay.....	18.1
Furaloids in furfural from excrement.....	10.7

The furaloid-yielding bodies have disappeared to a greater extent than the pentosans, and must be digested. From the above figures, their digestibility would be about 75 per cent compared with 60 per cent for that of the pentosans.

DETERMINATION OF PENTOSANS.

It appeared possible that the substances here called furaloid was formed from the true pentosans (anhydrides of pentose sugars) by distillation with hydrochloric acid, and their presence did not affect the pentosan determination. The contrary seems to be true. To test this point, a pentose sugar was prepared and tested in the following way: Finely ground corn cobs were extracted with dilute ammonia, and hydrolized with dilute hydrochloric acid. The acid was neutralized with lead carbonate, the liquid evaporated to a small volume, two volumes of alcohol added, and filtered. The filtrate was evaporated to a small volume, and xylose No. 1 precipitated with absolute alcohol. The alcohol was partly evaporated, water added, and the solution saturated in the cold with barium hydroxide. The impure barium compound of the sugars was precipitated by adding alcohol (xylose No. 2). Both of these materials were impure, but sufficiently pure for the end in view.

They were distilled with hydrochloric acid, and furaloid determined in the crude furfural of the distillate. The weights of the precipitates were:

	Xylose No. 1.		Xylose No. 2.		
Undistilled..	0.1555	0.1594	0.0257	0.0250	gram.
Distilled	0.1524	0.1530	0.0257	0.0240	
Loss, per cent	2	4	0	0	

With these figures may be compared those obtained from the products of the hydrolysis of corn bran, timothy hay, and crimson clover hay. In detail these were:

	Bran.	T. Hay.	C. C. Hay.	
Undistilled.....	0.5025	0.2891	0.0829	gram.
Distilled.....	0.5025	0.2680	0.0772	
Loss	0000	.0110	.0057	
Loss, per cent.	0	7.3	7	

Allowing for error of analysis, the differences are small. It seems probable that furaloids are not formed by distilling pentose sugars with hydrochloric acid. Accepting this as true, it is evident that the presence of furaloids in the crude furfural affects the determination of the pentoses. Until we know more about the pentosans, and the furaloid-yielding substances, it is questionable whether it would be expedient to determine them separately, since they can very conveniently be grouped together. A method of separating the furaloid from the crude furfural was tested, as follows: The vegetable material was

heated two hours under a reflux condenser with hydrochloric acid, instead of distilling off directly. The condenser was then turned down, and the furfural distilled as usual. A brown substance was deposited in the tube of the condenser. Furaloids were determined in the distillate, and found to be: Timothy hay, 1 per cent; okra hulls, 5 per cent; excrement, 3 per cent; corn silage, 14 per cent of the crude furfural. The furaloids were destroyed, except in the case of the silage. It is feared that this method would give too low results on furfural.

SUMMARY.

Pentosoids can be divided into the following classes: (1) Water-soluble pentosans. (2) Pentosans soluble in hot dilute acids. (3) Alkali-soluble pentosans--"wood-gum." These are not excluded from class 2. (4) Furfuroids. This includes the furfural-yielding constituents of lignin, oxycellulose, etc.

Methyl pentosoids are found in nature.

A method of determining pentosoid-free crude fiber should be used.

Pentoses and pentosoids are assimilated and utilized by herbivorous animals.

The distillate from vegetable materials with hydrochloric acid may contain fatty acids, a substance which separates as a black precipitate if the vessel is allowed to stand, and a substance or substances which is destroyed by distilling again (furaloid). All of these may appear in the phloroglucol precipitate.

The furaloid-yielding bodies were found in all the materials tested, the crude furfural in the hydrochloric acid distillate containing from 7 to 23 per cent furaloid.

The furaloid-yielding bodies are hydrolized with boiling 1¼ per cent sulphuric acid, and lost in the subsequent evaporation. They are digested to a greater extent than the total pentosans in the one sample of timothy hay excrement tested.

The furaloid does not arise from the action of the hydrochloric acid on pentose sugars.